DRAFT
SACRAMENTO RIVER TEMPERATURE MANAGEMENT PLAN FOR WATER YEAR 2023

INTRODUCTION

Conditions in the Central Valley this winter season have been very cold and wet, and consequently, Shasta temperature management will be much improved over the last few years. The Northern Sierra Precipitation 8-Station Index indicates that this year's hydrologic conditions are nearly 10 inches more than average. In mid-April, Shasta Reservoir's cold water pool used to protect winter-run Chinook salmon was projected to be comparable to other wet years such as 2017 and 2019. This Water Year 2023 Sacramento River Temperature Management Plan (Plan) reflects coordination starting in February 2023 to manage operations of Shasta Reservoir for water temperatures on the Sacramento River using conservative assumptions in modeling, taking advantage of opportunities to increase the cold water pool, and managing to real-time conditions. The Plan describes how the U.S. Bureau of Reclamation (Reclamation) plans to operate Shasta Reservoir and the Temperature Control Device (TCD) on Shasta Dam consistent with the 2020 Record of Decision on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project (LTO) in compliance with:

- RPM 1.a. of the 2019 National Marine Fisheries Service (NMFS) Biological Opinion to, in coordination with the Sacramento River Temperature Task Group (SRTTG), consider technical assistance from NMFS regarding the development of an annual temperature management plan and to submit a final temperature management plan to NMFS by May 20 of each year;
- Order 90-5 to consult with the California Department of Fish and Wildlife (CDFW), U.S. Fish and Wildlife Service (USFWS), NMFS, and Western Area Power Administration on the designation of a location upstream of the Red Bluff Diversion Dam where Reclamation will meet a daily average water temperature of 56°F; and
- Order 90-5 to provide an operation plan to the State Water Resources Control Board (SWRCB), Chief of the Division of Water Rights, on Reclamation's strategy to meet the temperature requirement at a location upstream of the Red Bluff Diversion Dam.
- The Interim Operations Plan (IOP), ordered by the US District Court on February 28, 2023, which identified priorities and planning efforts for Shasta cold water pool management to meet operational priorities and species needs. This IOP included establishing a six-agency Shasta Planning Group (SPG) to work iteratively with the technical groups (e.g., SRTTG and USST) to solicit operational guidance and risk assessments and provide policy guidance as necessary.

The Plan establishes temperature locations and targets through October 31, and estimates winter-run Chinook salmon egg mortality, dates for operation of the side gates on the TCD, and end of September cold water pool. Reclamation will monitor the cold water pool, compare measured conditions to actual performance during implementation, and provide regular updates through the SRTTG throughout Plan implementation.

Based on the March 90% forecast, Reclamation identified that Water Year 2023 was likely to be a Tier 1 year. In a Tier 1 year, there is more than 2.8 MAF of total storage in Shasta Reservoir at the beginning of

May, and Reclamation can meet 53.5°F at CCR. Conditions on April 1 along with modeling based on measured reservoir profiles confirm that WY2023 is a Tier 1 temperature management season.

MODELING ASSUMPTIONS, LIMITATIONS, AND OTHER UNCERTAINTIES

A seasonal water temperature forecast describes future expected downstream water temperature. This forecast, or simulation of expected water temperature performance is based on the targets specified in the TMP. Future water temperature is forecasted, using computational tools, at various elevations in the reservoirs and downstream in the river. These tools are based on conservative assumptions regarding hydrology, operations, and meteorology. Because this forecast (using conservative estimates in April to estimate what might happen at the end of October) can never exactly predict the actual hydrology, operations, and meteorology, the model results are not expected to precisely match actual water temperatures. The expectation is, however, that forecasted downstream water temperatures generally have an accepted measure of error regardless of the uncertain future conditions. In this case, there are generally two types of simulation error; uncertainty of the future conditions (e.g. inputs such as meteorology) and inherent model error or bias. To better understand the inherent model error or bias, a hindcast evaluation is typically performed. A hindcast, rather than looking forward to forecast, simply uses the actual input/forcing data after it's observed (e.g. hydrology, operations, and meteorology) to determine how well the model reproduced a condition such as actual downstream water temperatures.

Reclamation has proposed the use of NOAA-NWS Local Three-Month Temperature Outlooks (L3MTO) and historical meteorology as a means of estimating air temperature expectations for modeling purposes. In coordination with SRTTG, Reclamation has the choice of five exceedance threshold options, varying from those that serve more conservative stream temperature planning (e.g., 10% exceedance) to those that serve more aggressive planning (e.g., 90% exceedance). In past years, SRTTG has recommended the use of a conservative approach that uses the 25% exceedance L3MTO forecast. Therefore, Reclamation's April model runs utilized historical 25% exceedance meteorology.

RELEASE OUTLOOK

The Shasta Reservoir release strategy included in this plan and temperature modeling is based on the CVP's April forecast of operations. This release schedule is intended to guide the monthly average releases from Keswick Dam. Daily releases may vary from these flows to adjust for real-time operations. Trinity River releases below Lewiston Dam were based on a forecasted Wet Year type and diversions through Carr Powerplant were adjusted to balance storage, flow, and water temperature goals. Significant uncertainties exist within the forecast that will require intensive real-time operations management throughout the summer to achieve the various goals and targets throughout the system. Reclamation commits to reporting out on the status of this release outlook, temperature management, and overall system operations at the monthly SRTTG meetings. Table 1 describes the monthly forecasted operations for releases and storage targets which were taken from the April 90% CVP forecast of operation (Attachment 1).

Table 1. Monthly forecasted operations for Shasta and Keswick reservoir releases and storage estimates.

Operations Information/Month	April	May	June	July	August	September
Shasta Releases (TAF)	229	615	476	553	506	416
Keswick Releases (cfs)	4,300	10,000	8,000	9,000	8,000	7,000
Keswick Releases (TAF)	256	615	476	553	506	416
Spring Creek Power Plant (TAF)	27	0	0	0	0	0
Shasta End-of-Month Storage (TAF)	4,362	4,343	4,195	3,865	3,538	3,302

KEY AREAS OF UNCERTAINTY

Operational decisions on the upper Sacramento River are influenced by local and CVP and SWP system-wide multi-purpose objectives, including those that are planned and uncertain. Many factors contribute to operational actions including, but not limited to: flood protection, forecasted inflows, facility maintenance schedules, physical/mechanical facility limitations, upstream operations, minimum in-stream flow criteria, public health and safety criteria, downstream Delta regulatory requirements, Delta exports, power generation, recreation, fish hatchery accommodations, temperature management capabilities, and others. In addition, uncertain or unplanned events can also influence real-time operation decisions (e.g., wildfires and equipment malfunctions). To address uncertainty, Reclamation typically uses conservative estimates of future conditions in the modeling assumptions (e.g., hydrology, operations, and meteorology) and projections are updated through the management period.

The release forecast and temperature modeling used for this temperature management plan is based on a number of assumptions that each come with a level of uncertainty. A brief list of these uncertainty areas is listed below:

- Inflow hydrology
- Meteorology
- Reservoir stratification
- Accretions and depletions
- Public health and safety demands
- Infrastructure limitations
- Low River flow challenges
- Trinity River imports and Trinity River temperature management
- Low flow river and reservoir thermodynamics
- Delta water quality

TEMPERATURE STRATEGY

The Keswick Reservoir release schedule was developed by Reclamation as part of the April forecast of operations. Reclamation completed HEC-5Q modeling on April 24, 2023. The temperature modeling is presented here and is reflected in resulting biological and water supply performance metrics as shown in Table 2, Table 3, and Attachment 2. Further refinement to the temperature management strategy will occur through coordination with SRTTG and SPG as the season progresses.

Table 2. Estimated water temperature in degrees Fahrenheit at Shasta, Keswick and CCR based on April 24 model run. HEC-5Q does not perform well after mid-September. Water temperatures may be warmer than these targets and HEC-5Q results. Warmer water temperatures described in Attachment 2 describe the late season water temperatures that were used for the temperature dependent mortality modeling.

Month	Shasta	Keswick	CCR
May	49.7	51.2	52.1
June	49.0	51.3	52.7
July	49.9	52.0	53.0
August	49.8	52.0	53.1
September	50.1	51.8	52.7
October	50.0	51.5	52.2
November	50.0	50.5	50.9

Trinity River and Clear Creek modeled temperatures are included in Attachment 2.

Table 3. Fish and water performance metrics.

Metric	April 24 Scenario
Stage-independent TDM	0%
Stage-dependent TDM	1%
End of Sept CWP Storage (TAF)	1.27 MAF
First Side Gate Use	N/A
Full Side Gate	N/A
End of September Storage (MAF)	3.3 MAF

Reclamation will continue to coordinate through SRTTG to review these and other model results and may update these TDM estimates based on those discussions.

Attachment 1

Estimated CVP Operations 90% Exceedance

Storages

Federal End of the Month Storage/Elevation (TAF/Feet)

Facility	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Trinity	**910**	**858**	**974**	**1130**	**1126**	**1078**	**1032**	**1018**	**1015**	**1036**	**1070**	**1156**	**1267**
Elevation		2238	2252	2269	2269	2264	2259	2257	2257	2259	2263	2272	2283
Whiskeytown	**228**	**238**	**238**	**238**	**238**	**238**	**238**	**206**	**206**	**206**	**206**	**206**	**206**
Elevation		1209	1209	1209	1209	1209	1209	1199	1199	1199	1199	1199	1199
Shasta	**3771**	**4362**	**4343**	**4195**	**3865**	**3538**	**3302**	**3195**	**3173**	**3216**	**3333**	**3610**	**3749**
Elevation		1061	1060	1055	1043	1030	1021	1016	1015	1017	1022	1033	1038
Folsom	**667**	**812**	**950**	**911**	**794**	**669**	**661**	**578**	**502**	**442**	**447**	**527**	**677**
Elevation		451	464	460	449	436	435	426	417	409	410	420	437
New Melones	**1393**	**1478**	**1682**	**1887**	**1915**	**1879**	**1865**	**1821**	**1834**	**1848**	**1861**	**1874**	**1901**
Elevation		1001	1022	1042	1044	1041	1040	1036	1037	1038	1039	1041	1043
Federal San Luis	**928**	**964**	**877**	**697**	**353**	**113**	**82**	**69**	**93**	**197**	**339**	**275**	**353**
Elevation													
Total	7897	8711	9063	9058	8291	7514	7181	6887	6823	6944	7255	7647	8153

State End of the Month Reservoir Storage (TAF/Feet)

Facility	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Oroville	**2908**	**3203**	**3323**	**3318**	**2722**	**2270**	**1926**	**1819**	**1702**	**1658**	**1808**	**2060**	**2340**
Elevation		878	886	886	844	807	776	765	753	748	764	788	813
State San Luis	**1062**	**1027**	**1059**	**990**	**939**	**873**	**896**	**643**	**542**	**498**	**553**	**576**	**600**
Elevation													
Total San Luis (TAF)	**1990**	**1991**	**1936**	**1687**	**1291**	**986**	**979**	**712**	**635**	**695**	**891**	**851**	**953**
Elevation		540	536	515	481	451	451	422	414	421	442	437	448

Monthly River Releases (TAF/cfs)

Facility	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Trinity		309	257	38	28	53	52	23	18	18	18	17	18
cfs		**5,194**	**4,188**	**639**	**456**	**857**	**870**	**373**	**300**	**300**	**300**	**300**	**300**
Clear Creek		12	17	17	9	9	9	12	12	12	12	11	22
cfs		**200**	**281**	**284**	**150**	**150**	**150**	**200**	**200**	**200**	**200**	**200**	**363**
Sacramento		256	615	476	553	506	416	342	268	277	277	250	492
cfs		**4300**	**10000**	**8000**	**9000**	**8225**	**7000**	**5571**	**4500**	**4500**	**4500**	**4500**	**8000**
American		416	461	416	277	246	119	123	119	123	108	83	92
cfs		**7000**	**7500**	**7000**	**4500**	**4000**	**2000**	**2000**	**2000**	**2000**	**1750**	**1500**	**1500**
Stanislaus		83	96	56	18	18	18	49	12	12	13	12	12
cfs		**1400**	**1555**	**940**	**300**	**300**	**300**	**797**	**200**	**200**	**219**	**221**	**200**
Feather		595	633	321	418	424	428	135	104	108	108	97	108
cfs		**10000**	**10300**	**5400**	**6800**	**6900**	**7200**	**2200**	**1750**	**1750**	**1750**	**1750**	**1750**

Trinity Diversions (TAF)

Facility	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Carr PP		0	1	11	9	10	9	0	6	1	1	2	1
Spring Crk. PP		**27**	**0**	**0**	**0**	**0**	**0**	**22**	**0**	**1**	**8**	**20**	**6**

Delta Summary (TAF)

Facility/Location/Metric	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Tracy		144	215	250	265	265	255	165	136	186	225	66	235
USBR Banks		0	0	0	0	0	0	42	42	42	0	0	0
Contra Costa		9.5	9.5	9.5	7.4	8.3	9.5	14.0	14.0	14.0	13.7	13.7	10.5
Total USBR		153	225	260	272	273	265	221	192	242	239	80	246
State Export		244	332	363	439	441	426	83	192	229	155	105	160
Total Export		397	557	623	711	714	691	304	384	471	394	185	406
COA Balance		18	18	18	18	18	18	18	18	18	18	17	17
Vernalis TAF		1660	1555	818	444	260	207	172	74	75	76	82	98
Vernalis cfs		27904	25294	13749	7230	4237	3477	2798	1242	1225	1244	1482	1599
Old/Middle R. calc. cfs		6,827	3,819	-2,460	-6,247	-7,631	-7,963	-3,139	-5,001	-5,938	-4,962	-2,484	-4,950
Computed DOI cfs		55690	48981	22357	10281	6881	7800	8426	5497	7271	9142	11400	13307
Excess Outflow		27669	23213	3833	2277	2879	4791	944	992	2765	3140	0	1903
% Export/Inflow		10%	15%	28%	44%	52%	52%	32%	49%	48%	42%	21%	33%
% Export/Inflow std.		35%	35%	35%	65%	65%	65%	65%	65%	65%	65%	45%	35%

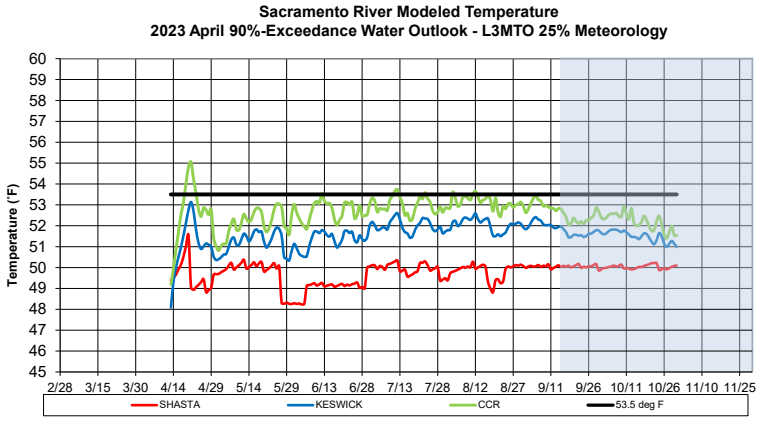
Hydrology

		Trinity		Shasta		Folsom		New Melones	
Water Year Inflow (TAF)		1430		5,593		4,437		2232	
Year to Date + Forecasted	% of mean	118%		101%		163%		211%	

CVP actual operations do not follow any forecasted operation or outlook; actual operations are based on real-time conditions.
CVP operational forecasts or outlooks represent general system-wide dynamics and do not necessarily address specific watershed/tributary details.
CVP releases or export values represent monthly averages.
CVP Operations are updated monthly as new hydrology information is made available December through May.

4/18/2023

Attachment 2



	Shasta	Keswick	CCR	Igo	Trinity	Lewiston
	deg F	deg F	deg F	deg F	deg F	deg F
Apr	49.6	51.1	52.6	47.3	42.9	43.9
May	49.7	51.2	52.1	47.5	44.7	46.0
Jun	49.0	51.3	52.7	48.8	46.3	52.2
Jul	49.9	52.0	53.0	51.0	47.1	53.5
Aug	49.8	52.0	53.1	51.6	48.2	53.0
Sep	50.1	51.8	52.7	51.2	49.4	52.6
Oct	50.0	51.5	52.2	51.0	50.4	54.2
Nov	50.0	50.5	50.9	52.0	50.6	51.8

Run date: 4/24/23

EOM Sept storage: 3.3 MAF

Trinity profile date: 4/12/23

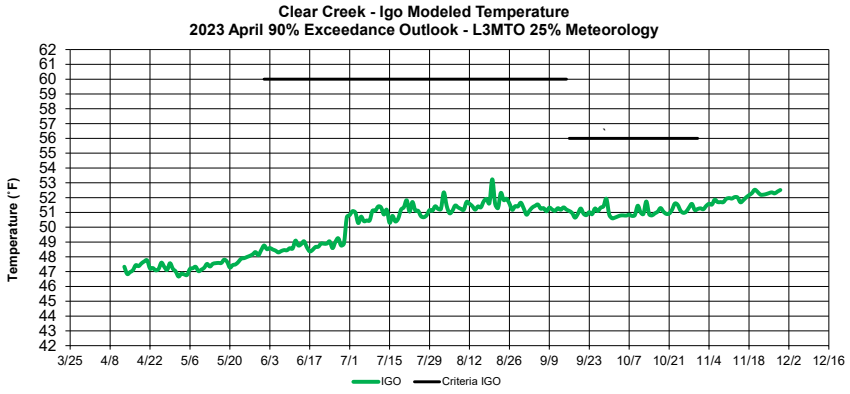
Whiskeytown profile date: 4/11/23

Shasta profile date: 4/13/23

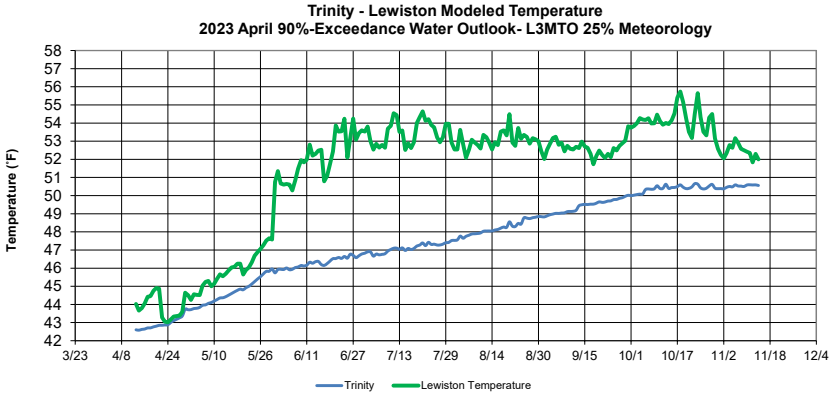
Projected Side gates: First n/a Full n/a

Shaded area denotes period of model limitations - see Fall Temperature Index

End of September Cold-Water-Pool less than 56 deg F: 1.27 MAF



	Igo
	deg F
Apr	47.3
May	47.5
Jun	48.8
Jul	51.0
Aug	51.6
Sep	51.2
Oct	51.0
Nov	52.0



	Trinity	Lewiston
	deg F	deg F
Apr	42.9	43.9
May	44.7	46.0
Jun	46.3	52.2
Jul	47.1	53.5
Aug	48.2	53.0
Sep	49.4	52.6
Oct	50.4	54.2
Nov	50.6	51.8

Attachment 3

Biological Modeling

Spatially-explicit daily average Sacramento River water temperatures forecasts from the HEC-5Q model results are used as inputs to generate temperature-dependent egg mortality estimates. For this period, modeled temperatures, actual temperatures until April 24, 2023, and modeled temperatures after that, on the Sacramento River at Keswick Dam, above Highway 44, above Clear Creek, and Balls Ferry bridge, and interpolated temperatures at other locations are used to estimate temperatures at river miles where simulated redds were located.

Temperature-dependent egg mortality estimates are calculated by modeling a redd's lifetime based on the days required to cross a known cumulative degree-day threshold and estimating mortality as an increasing function of temperature past a temperature threshold. Martin et al (2017) was used to estimate stage-independent modeling whereby a single temperature threshold is used from spawning and incubation through emergence (Figure 1). Anderson et al. (2021) was used to estimate stage-dependent modeling for targeting different temperatures before, during, and after the most sensitive stages during egg incubation (Figure 2). The methods are applied to a set of simulated redds representative of redd construction timing and location from 2016-2021 and the results summarized on a population level for comparison. Further information about the model's assumptions are documented in Table 4 below.

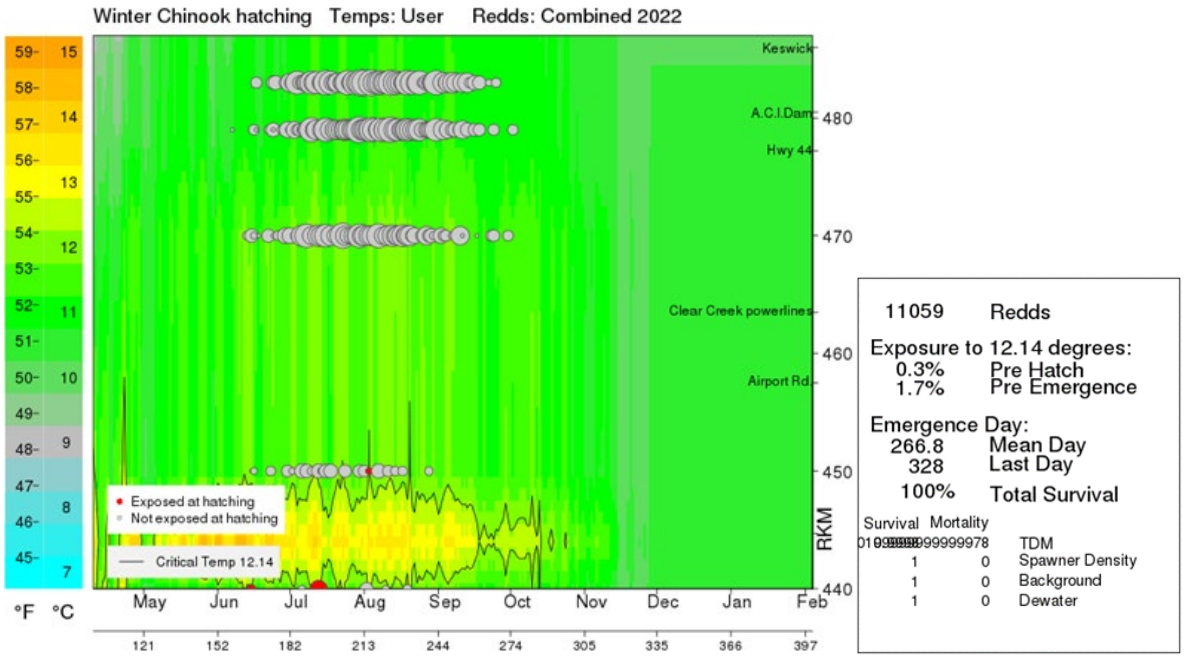


Figure 1. April 24 temperature landscape with modeled temperatures starting April 25 and 2000-2022 redd locations and timing (Stage-independent mortality).

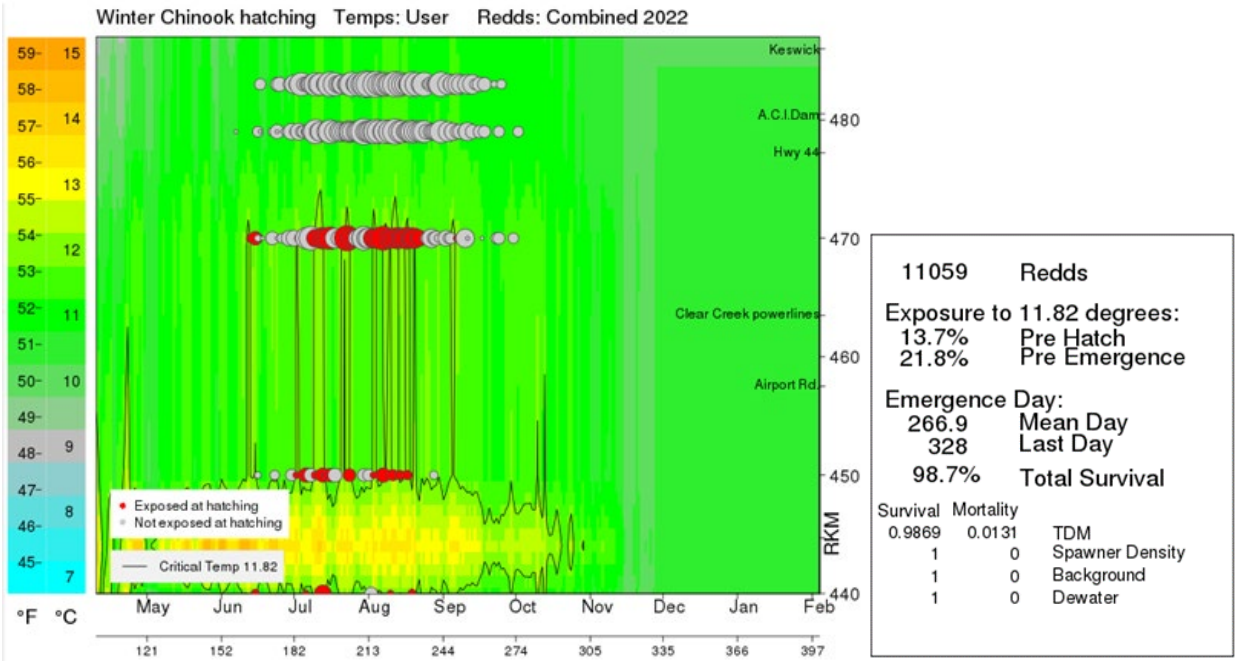


Figure 2. April 24 temperature landscape with modeled temperatures starting April 25 and 2000-2022 redd locations and timing (Stage-dependent mortality).

Table 4. Biological modeling parameter information.

Parameter	April 24, 2023 Scenario
Meteorology source	L3MTO Meteorology 25%
Time period	1/1/23-4/24/23: Observed temperature 4/25/23-11/29/23: Simulated
Reservoir Model used	HEC-5Q
River Model used	HEC-5Q
Shasta Profile date	4/13/23
TCD Gate operations	HEC-5Q
Sacramento water temperatures used	HEC-5Q output at Keswick, Highway 44, Clear Creek, and Balls Ferry.
Biological Model used	SacPAS Fish model (Temperature effect only)
Temperature Mortality Models	Stage-independent mortality Stage-dependent mortality
Egg emergence timing model	Linear. 958 ATUs (degrees C), as indicated for Zeug et al. on SacPAS under Egg to emergence timing model.
TDM redd time distribution	Aerial Surveys 2000-2022 (11,059 redds)
TDM redd space distribution	Aerial Surveys 2000-2022 (11,059 redds)
TDM Tcrit (50th percentile)	Stage-independent mortality: 12.14°C Stage-dependent mortality: 11.82°C
TDM bT (50th percentile)	Stage-independent mortality: $0.026°C^{-1}d^{-1}$ Stage-dependent mortality: $0.436°C^{-1}d^{-1}$
Critical Days	Stage-independent mortality: All Stage-dependent mortality: 4 days
TDM estimate	See Figures 1 and 2